Status of InSight
Entry, Descent, and Landing

Gene Bonfiglio, Myron R. Grover, & Brooke Harper

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Topics We'll Discuss…

- Brief overview/status of current mission (<1 minute)

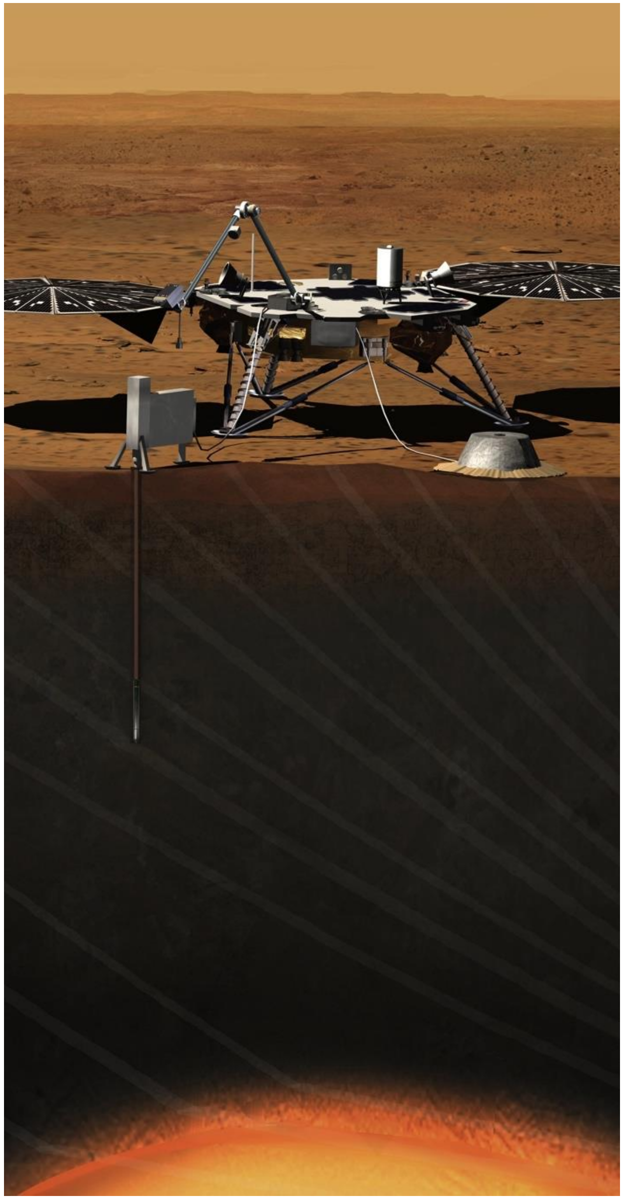
- InSight (NSYT) challenges regarding radar/heatshield interaction (~ 5 minutes)
  - Improvements to the radar activation timer that mitigate radar/heatshield interaction issues

- Final maneuver design sensitivity to changes in EDL-day atmosphere knowledge (~ 5 minutes)
  - Changes to maneuver design process as a result

Lot's of information here. Please find me later if you're interested in a more thorough explanation

Brief Mission Status

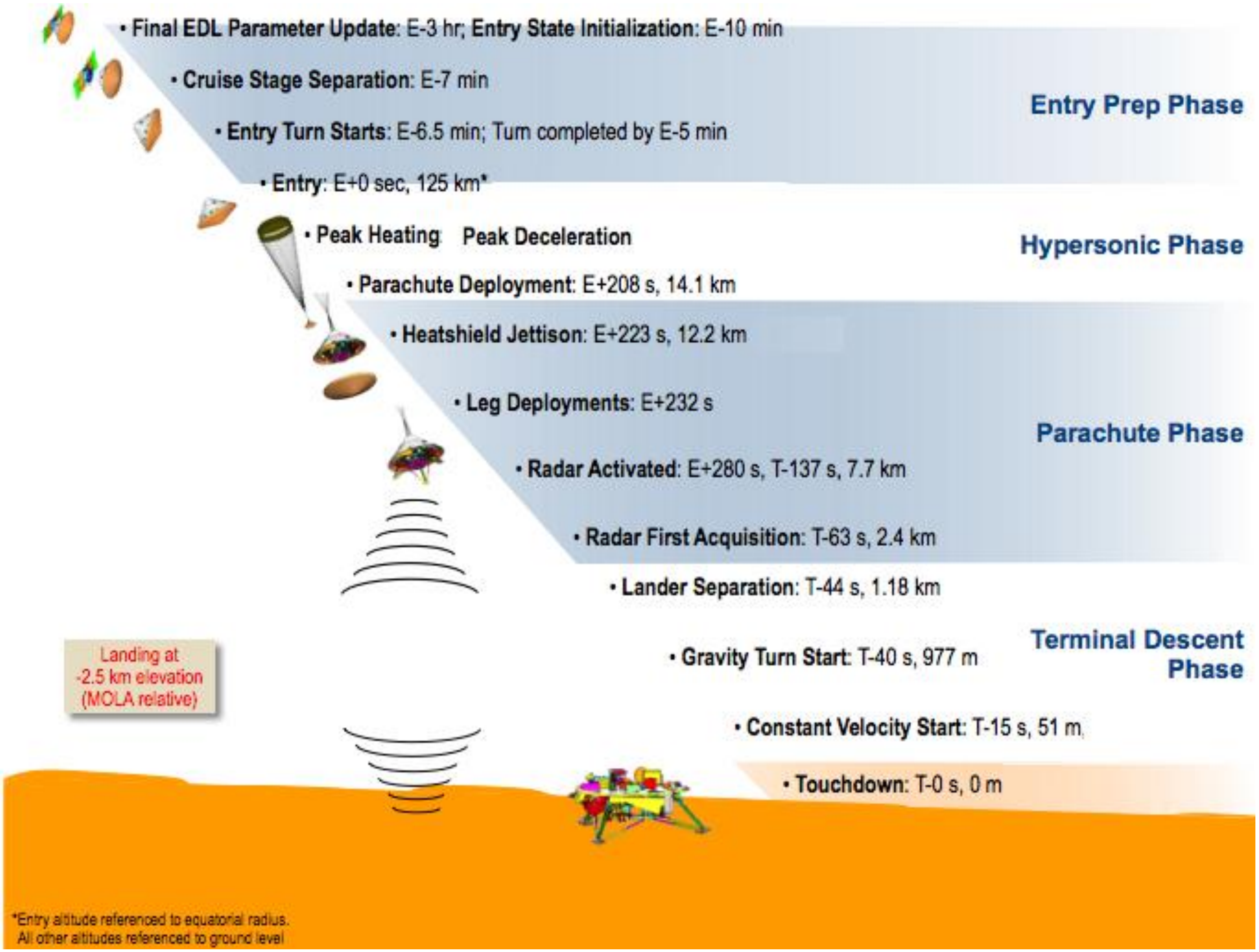
Brief Overview of NSYT



- Mars lander launching in 2018
- Will take thermal gradient and seismic measurements to better understand:
  - Martian tectonic activity
  - Evolutionary formation of rocky planets
- Very few details have changed since last year's status
- I'll focus on some interesting technical problems that the EDL team has faced in development

Entry, Descent, and Landing Overview

- InSight EDL design is mature – minimal design changes from Phoenix

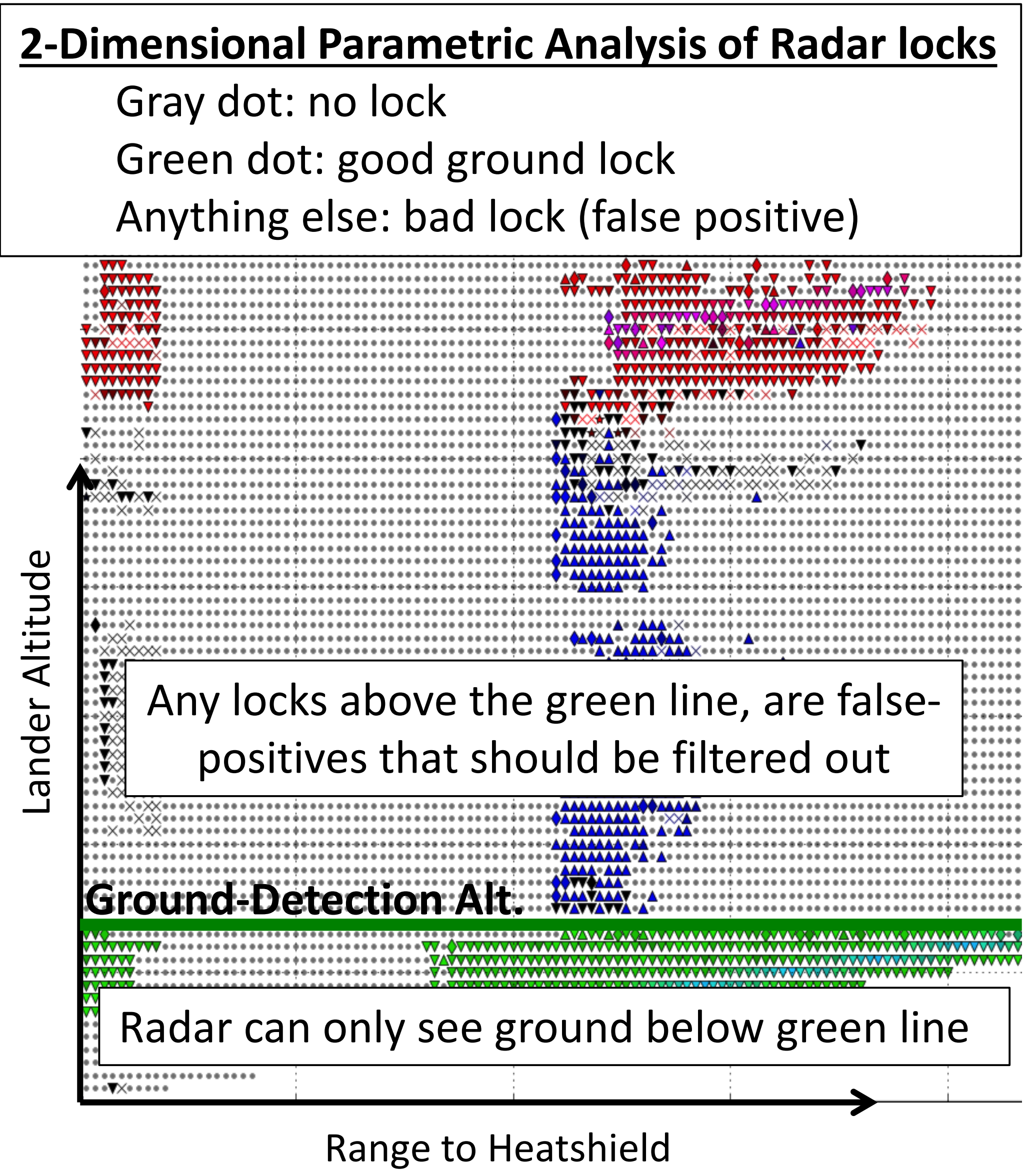


Radar-Heatshield Interactions

NSYT Radar

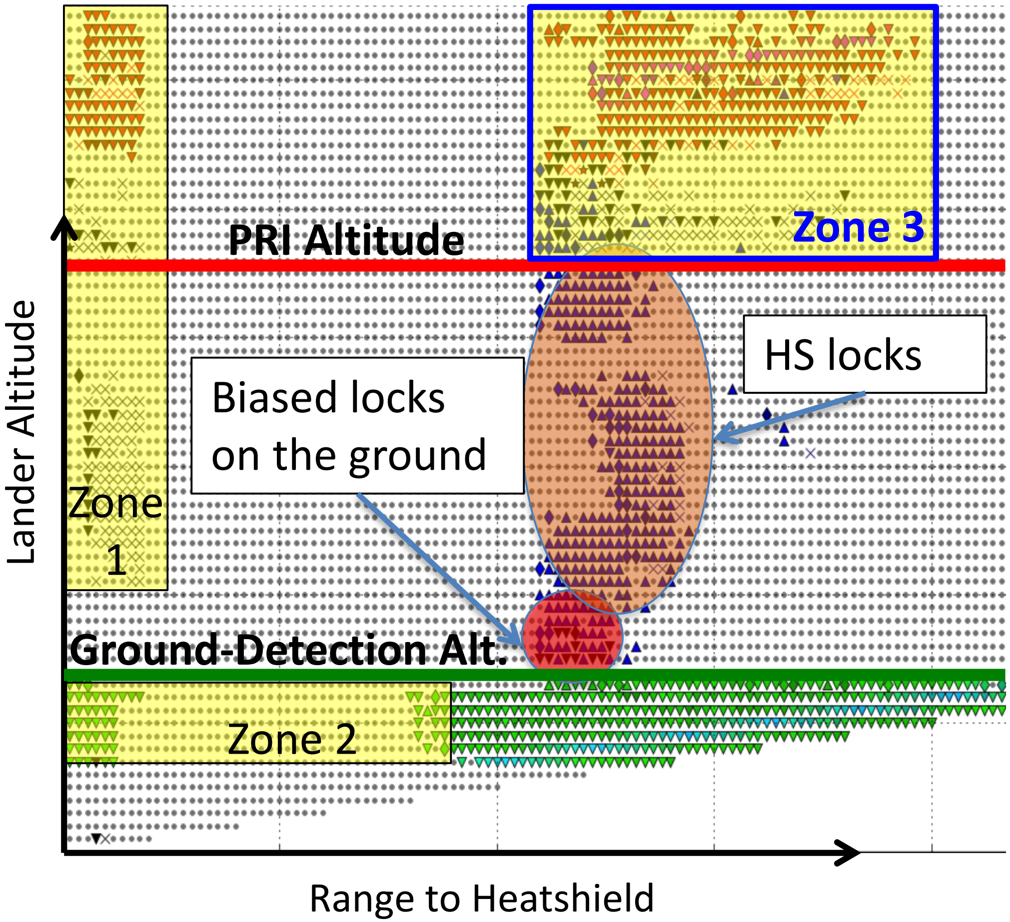
- NSYT uses a radar to get accurate altitude and velocity measurements
- When the radar is activated, it radiates pulses to search for the ground and determine true lander altitude
- There is a large altitude uncertainty associated with radar activation
- The radar should be activated higher than the minimum altitude at which it can detect the ground
- Under certain conditions, however, the heatshield (HS) can cause false positives from the radar (i.e. radar lock on something other than the ground)

NSYT Radar Activation



- Radar can't detect the actual ground until it's below green line (anything above green line is a false-positive)
- Above the green line, the HS can confuse the radar by reflecting pulses before they reach the ground
- Presence of the heatshield, leaves NYST radar vulnerable to false-positives above green line

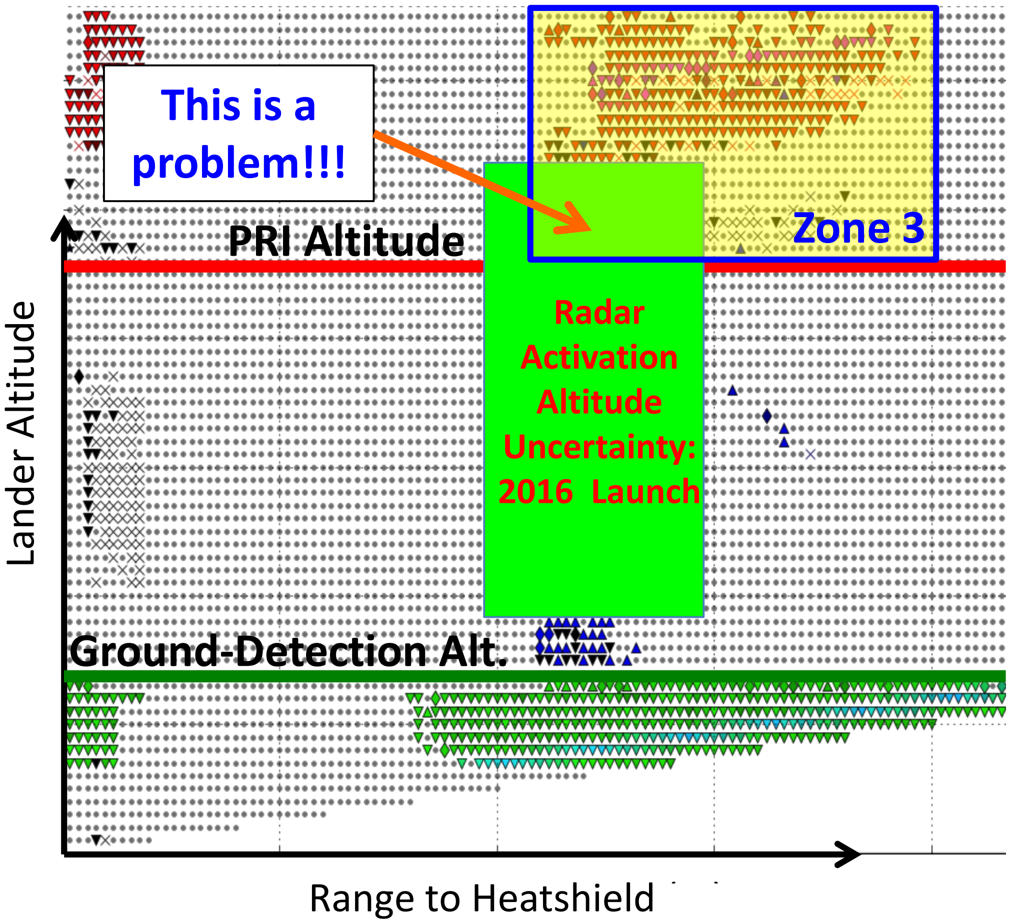
Radar Vulnerability Zones



We want to activate radar between red and green lines

- **Zone 1 & 2**: Easily avoided by delaying radar activation
- **Zone 3:**
  - HS-induced ambiguities
  - Behaves like a ground lock so it is undetectable
  - Mitigation: Delay radar activation avoids most ambiguities from Zone 3
- **Orange Oval**: Detectable by flight software
- **Red Circle**: Radar sees biased reflection of the ground...certain death
  - Cannot be avoided but very low likelihood

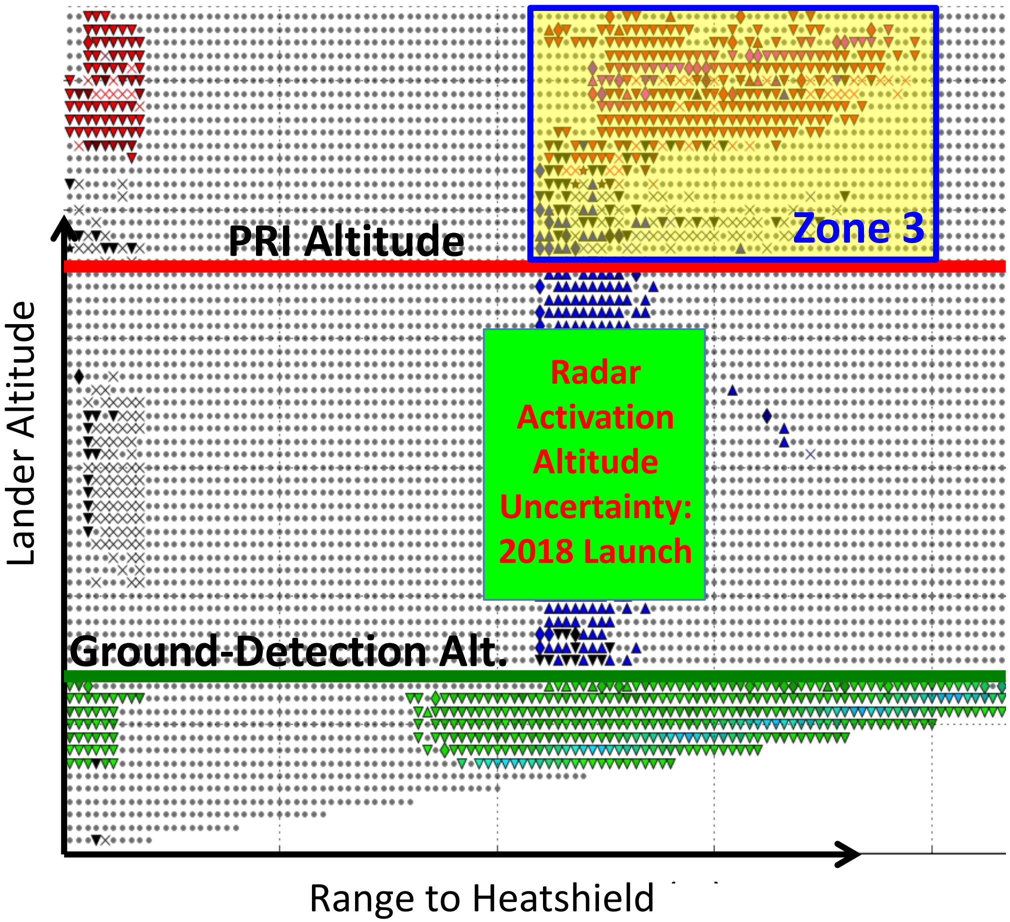
Radar Activation Altitude Uncertainty: 2016 Launch



Simple fixed timer causes radar activation to violated constraints

- NSYT vulnerable to HS-induced radar ambiguities (**Zone 3**)
- In 2016, radar activation was a simple fixed timer relative to parachute deploy
  - Large radar activation altitude uncertainty
- Likelihood of HS-induced ambiguities was low

Radar Activation Altitude Uncertainty: 2018 Launch



Dynamic timer based on velocity knowledge reduces uncertainty

- Radar activation timer is no longer a simple fixed timer
- NSYT now uses navigated velocity at parachute deploy to calculate and actively set radar activation timer during EDL
- Result: reduces altitude uncertainty and eliminates vulnerability to HS-induced radar ambiguities!

Maneuver Design Sensitivity to Atmosphere Knowledge Updates

Problem: Maneuver Design Sensitivity to Atmosphere Updates

- NSYT discovered that small updates in atmosphere knowledge can cause large, unexpected fluctuations in the final trajectory correction maneuver (TCM)

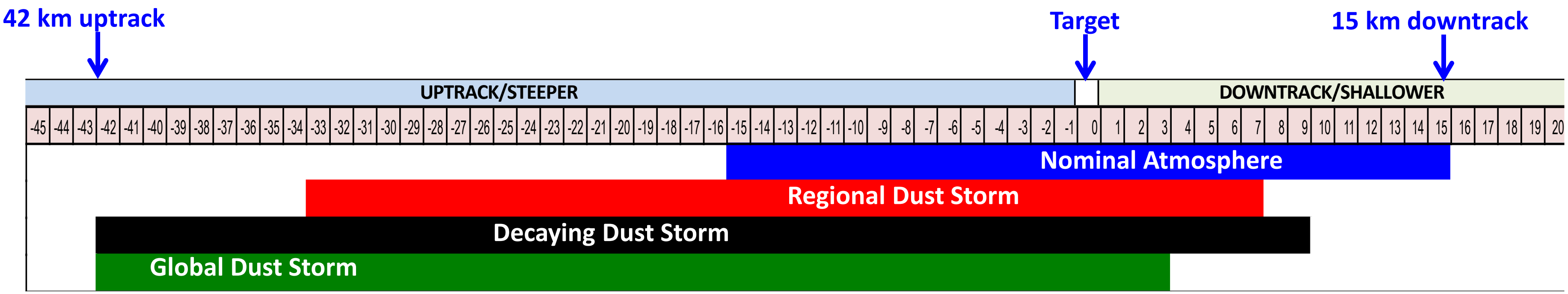
- Navigation uses an iterative targeting process to design TCMs
  - The process used ensures the nominal EDL trajectory hits the desired latitude and longitude

- Iterative process adjusts entry time but keeps both entry flight path angle (EFPA) target and ground target fixed

- Updates to the nominal atmosphere change the central angle of the nominal EDL trajectory
  - Changes to central angle result in large entry time deltas and very large TCMs at the final maneuver

Final Atmosphere Update Impact on Nominal Trajectory

Variability in Nominal Target Due to Atmosphere Updates



- Atmosphere updates can move nominal landing location 15 km downtrack or 42 km uptrack (dust storms)

- A shift on the ground of 20 km, caused by the atmosphere, would change entry time by 80 seconds and would require a TCM of ~5 m/s (10 times larger than we planned!)

- This issue is caused by an *improvement in atmosphere knowledge* that is *not* accounted for in the targeting process
  - Perfect atmosphere knowledge at final TCM would not help because it's the *improvement* in knowledge (relative to TCM-1) that causes the issue

Is this a real problem and how do we solve it???

- This is a real issue for any lander which updates their atmosphere based on pre-EDL measurements, and that doesn't have guidance.
- Only 2 viable ways to account for this in the TCM design:
  - Change ground target to be up/down track of desired target, based on how atmosphere update impacts nominal trajectory
  - Change nominal EFPA target so central angle of the nominal EDL trajectory changes, resulting in the nominal trajectory hitting the desired ground target

NSYT Targeting Strategy to Atmosphere Update Sensitivity

- Current plan is to define tolerances in EFPA target and ground target that will be used by the navigation team in the TCM targeting process

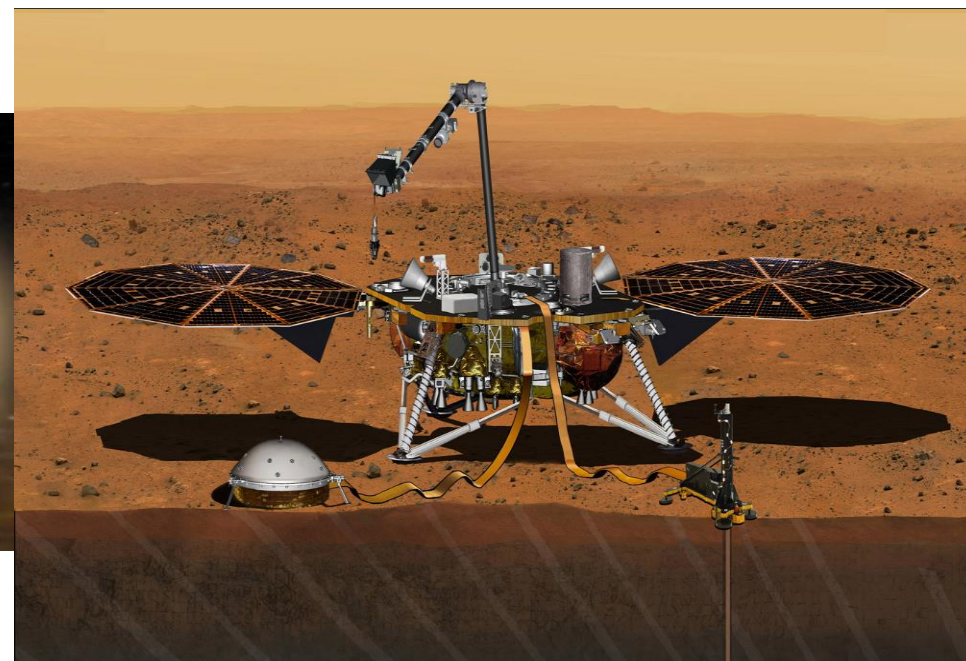
- Ground target tolerance is based on landing site safety assessment of regional terrain (tied to HiRISE imaging)

- EFPA target tolerance is based on system performance (aerothermal, gnc, etc.)

Project Milestones: Finish and Fly

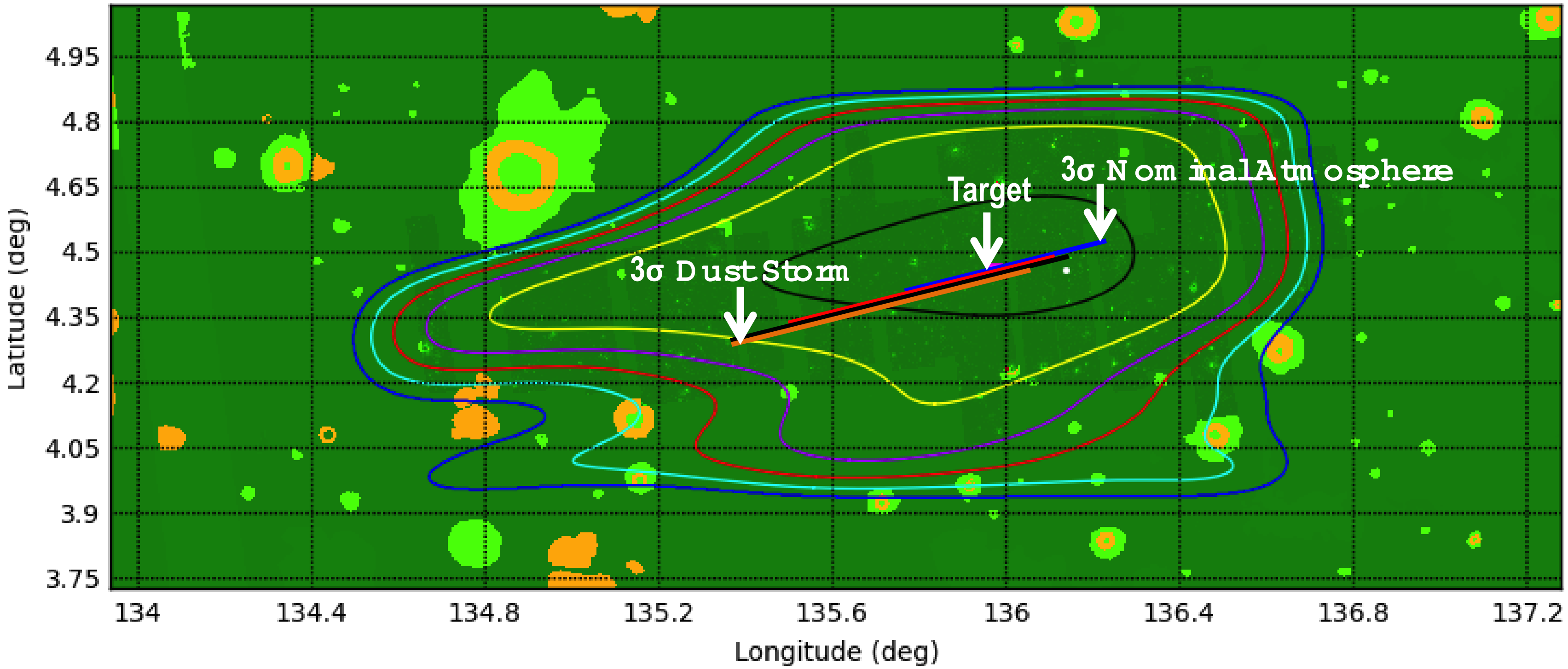
- Functional SEIS to ATLO – very soon!
- ATLO Re-Start – July 2017
- Spacecraft to Vandenberg Air Force Base – Feb 2018
- Launch Period – 5/5/2018 to 6/8/2018
- InSight EDL – 11/26/2018
- Onward to Mars!!!





BACKUP

Nominal Landing Ellipse Center



- If this knowledge is not accounted for, the actual targeted landing ellipse *__will not be centered at the desired target__*
- There are only 2 viable ways to account for this effect in the TCM design:
  - Update ground target to be uptrack or downtrack of the desired target, based on how the atmosphere update impacted the nominal trajectory
  - Update EFPA target so central angle of the nominal EDL trajectory changes, resulting in the nominal trajectory hitting the desired ground target

EDL Characteristics: 2018 vs. 2016

	2016 InSight	2018 InSight
Launch Period	March 4-30, 2016	**May 5-June 8, 2018**
Arrival Date	September 28, 2016	**November 26, 2018**
Entry Vehicle Mass	612.2 kg*	No change
Inertial Entry Velocity	6.02 km/s	**5.63 km/s**
Entry Flight Path Angle	-12.5° ± 0.21° (3σ)	**12.0 ± 0.21° (3σ)**
Landing Site Latitude	4.46°N	No change
Max Landing Site Elevation	-2.5 km (wrt MOLA)	No change
Ls / Dust Season	231° (Southern Mid-Spring/Global dust storm season)	**295° (Early Southern Summer/tapering Global dust storm season)**
Surface Characteristics	Smooth, flat surface / broken up regolith	No change

Entry, Descent, and Landing conditions in 2018 are either similar to or better than the 2016 opportunity

*Maximum expected value (MEV) from November 2015

NSYT Radar Issues

- For most of NSYT development, the project has dealt with issues related to heatshield (HS) interaction with the landing radar
- HS interactions with the radiated pulses can result in false-positives (ground locks reported by the radar that are not actually locks on the ground)
- These issues were dealt with on Phoenix as well but are more stressing for NSYT because of larger uncertainty in parachute deploy altitude than Phoenix dealt with